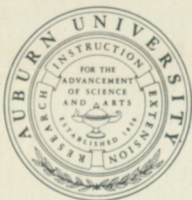


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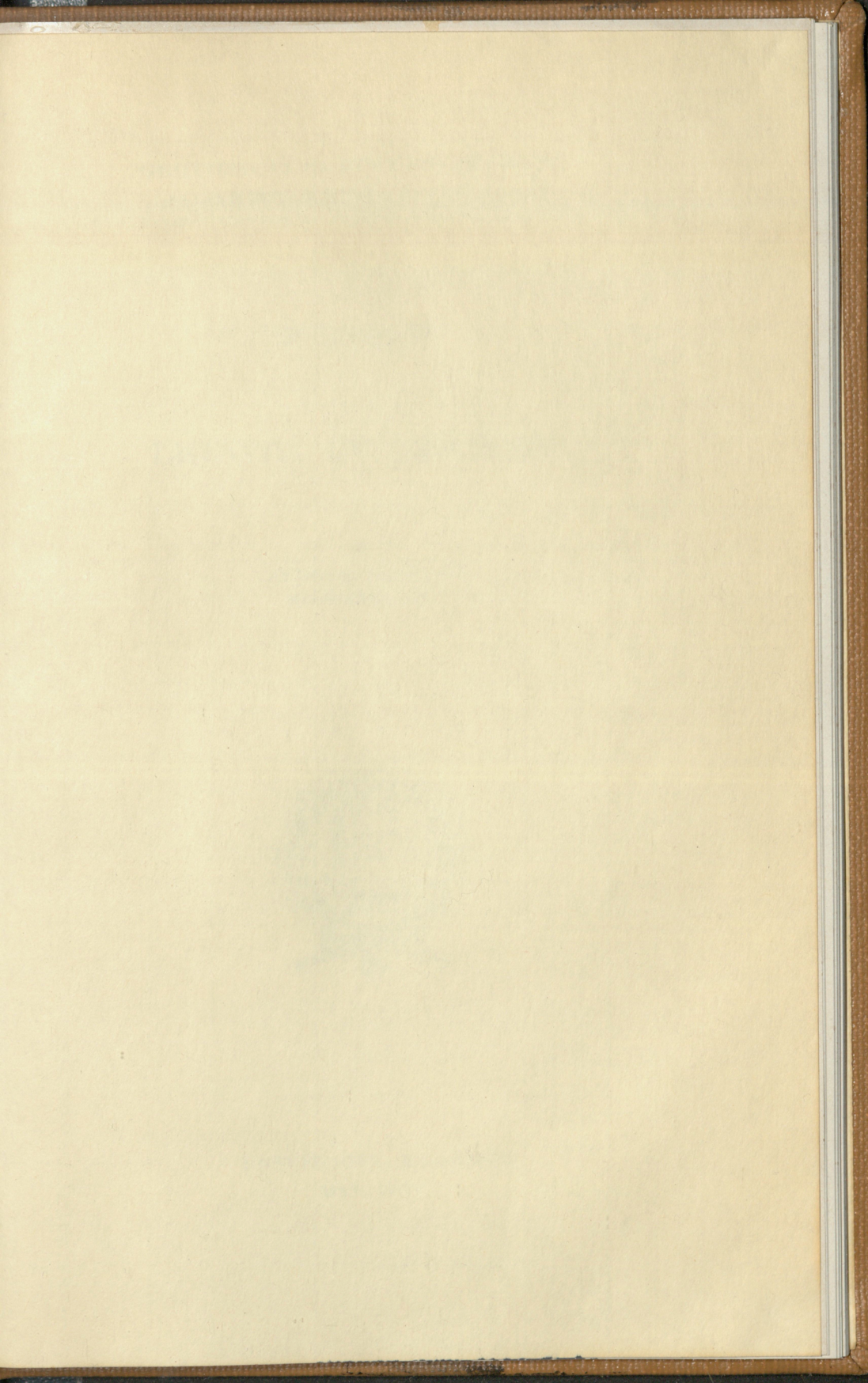
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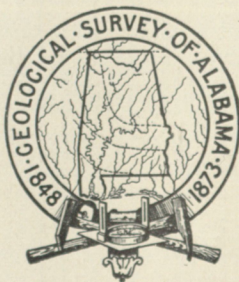


GEOLOGICAL SURVEY OF ALABAMA
WALTER BRYAN JONES, STATE GEOLOGIST

BULLETIN 33

LIGNITE IN ALABAMA

BY
JELKS BARNSDALE
STAFF GEOLOGIST



UNIVERSITY, ALABAMA
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LETTER OF TRANSMITTAL

University, Alabama,
April, 1929.

His Excellency,
BIBB GRAVES,
Governor of Alabama,
Montgomery, Alabama.

Sir:

I have the honor to transmit herewith the manuscript of a report entitled "Lignite in Alabama," by Jelks Barksdale, Staff Geologist, with the request that it be printed as Bulletin No. 33 of the Geological Survey of Alabama.

Very respectfully,

WALTER B. JONES,
State Geologist.

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TABLE OF CONTENTS

Introduction	Page 9
Physical Properties	10
Color; Streak; Hardness; Specific Gravity; Luster; Texture; Heating Value; Slacking upon Drying; Moisture.	
Chemical Properties.....	11
Composition of Combustible Portion; Composition of Ash; Proximate Method of Analysis; Ultimate Method of Analysis; Table of Analyses of Lignite and Bituminous Coal.	
Formation	12
Second Stage in Coal Formation; Formed from Land Plants; Several Seams in Vertical Section; Heat and Pressure Necessary for Transformation; Lignite in Younger Geological Formations.	
Mode of Occurrence	14
As Fragments in Sand; As Lignitized Logs; As Well Defined Beds; Exposures in Beds and Banks of Creeks, In Ravines, In Cuts; Springs Good Indications of Outcrops; Roof Material; Dark Colored Clay below Lignite.	
Thickness, Character and Quality of Beds.....	15
Greatest Development in Marengo and Wilcox Counties; Lignitic Clays and Sands; Pyrite; Uncertainty of Beds; Methods of Prospecting; Method of Calculating Available Tonnage.	
Geology of the Area	18
Wilcox Group, Formations of, Materials of; Stratigraphy; Topography; Lignite in the Nanafalia Formation; Materials of the Nanafalia; Bashi Formation; Tuscaloosa Formation; Hatchetigbee Formation; Geological Sections; Tuscaloosa Formation; Eutaw Formation; Sucarnoochee Formation.	
Stratigraphy	26
Stratigraphic Section of Southwest Alabama.	
Description of Outcrops by Counties.....	30
Barbour County; Choctaw County; Clarke County; Coffee County; Lamar County; Marengo County; Monroe County; Pike County; Sumter County; Tuscaloosa County; Wilcox County.	
Analysis of Lignite by Counties.....	46
Barbour County; Clarke County; Lamar County; Marengo County; Monroe County; Pike County; Sumter County; Wilcox County.	
Methods of Mining.....	51
Strip Pit Method; Overburden; Advantages of Open Pit Mines, Disadvantages; Underground Methods of Mining; Employed in Western States; Room and Pillar Method; Lignite Left for Roof; Ordinarily Little Water Encountered.	

TABLE OF CONTENTS—Continued

Production	Page 53
In the United States; In the Dominion of Canada; In Europe; Description of Beds and Available Tonnage in North Dakota and Texas.	
Uses	54
For Fuel Purposes, In the Raw State, In Powdered Form, In Colloidal Form, As Briquets; Methods of Briquetting; Bonding Materials Used, Organic, Inorganic; Gasified Lignite.	
Common Misconceptions	58
That Lignite Gets Thicker and Better Away from the Outcrop; That Hard Coal Occurs below the Lignite; "How long will it take lignite to change to stone coal."	
Conclusion	59
Lignite as a Fuel for the Manufacture of Cement, Lime, Pottery, Bricks; As a Fuel for Steam Plants Generating Electrical Power; Lignite Fired Steam Plant at Trinidad, Texas; Synthetic Gasoline; Lignite as a Domestic Fuel.	
Index	62

LIST OF ILLUSTRATIONS

	Page
Plate 1.—Outline map of Alabama showing areal extent of outcrop of the important lignite bearing formations.....	17
Plate 2.—Outline map of Alabama showing areal extent of outcrop of the minor lignite bearing formations.....	19
Plate 3.—Typical exposure of the <i>Ostrea thirsae</i> member of the Nanafalia formation one mile south of Kimbrough, Wilcox County.....	21
Plate 4.—	
A. Lignite outcrop in the bed of a small stream one-half mile south-east of Bakerhill, Barbour County.....	31
B. Lignite outcrop along the highway about two miles east of Magnolia, Marengo County.....	31
Plate 5.—Exposure of lignite in a cut along the highway five miles north of Thomasville, Clarke County.....	35
Plate 6.—Exposure of lignite in a bluff along Landrums Creek, Sec. 23, T. 14 N., R. 1 E., Marengo County.....	39
Plate 7.—Exposure of lignite in a cut along the Alabama, Tennessee and Northern Railroad five miles south of York, Sumter County.....	43

INTRODUCTION

The first published account of the occurrence of lignite in Alabama was by Michael Tuomey, in his report on the geology of the State which was issued in 1858. Since that time local residents have occasionally reported beds of this material, usually with the belief that they had found bituminous coal, but none of these deposits have been developed commercially.

In a state which has such an abundance of high grade bituminous coal it is natural that the lignite should have received little attention, since it is very much inferior to bituminous coal in heating value, and since it cannot be successfully stored or shipped because of its property of slacking or crumbling upon drying.

Recently considerable attention has been aroused concerning the possibility of developing these deposits commercially. Perhaps the most promising means of utilization would be as a fuel for the production of electrical power to be supplied in connection with hydroelectric power. Such power plants are in operation in other states at the present time.

There is also the possibility of its utilization as a basis for chemical industries, which would consume the by-products for the manufacture of chemicals and sell or use the carbonized material for fuel either untreated or in the form of briquets.

Run of mine lignite can be adapted to most domestic uses and upon briquetting it yields an excellent domestic fuel, although its price is thereby increased.

Since these deposits are of workable thickness and can be exploited at moderate cost by stripping, it is probable that they will be developed on a commercial scale in the near future.

This report is intended to afford information to those who may be interested in developing the lignite of the State.

PHYSICAL PROPERTIES

Lignite, sometimes known as brown coal, may be classified as immature coal which has passed through only one stage — peat — in the process of coal formation. The color varies from yellow to black but is usually dark brown. The streak which is obtained by rubbing the solid material on unglazed porcelain, is yellowish brown and of a somewhat lighter shade than the solid lignite. Its hardness is considerably less than that of bituminous coal. The specific gravity of run of mine lignite varies from 0.8 to 1.5, but is normally about 1.22; the samples exhibiting high specific gravities contain considerable amounts of ash which is much heavier than the combustible materials. It usually has a dull luster, but in some cases may be waxy, due to the presence of earthy impurities.

The original texture of the woody materials is generally well preserved, but in the better grades of lignite this texture may be practically obliterated. The lignite is distinctly jointed and usually comes from the mine in irregularly shaped slabs, but it may sometimes have a cubical fracture. It burns readily with a long smoky flame, and gives off an unpleasant odor in the process. The heating value is much less than that of bituminous coal, and for run of mine lignite varies from 5500 to 7000 British thermal units per pound, while the moisture and ash free material gives a heating value of from 10,000 to 12,000 B. t. u. per pound. Its most characteristic property is that of slacking or crumbling upon drying, which takes place upon exposure to the air as well as upon artificial drying. The freshly mined material often contains as much as thirty-five or even fifty per cent of water, a large part of which is driven off by air drying, but a considerable amount, frequently as much as fifteen to twenty per cent, remains which seems to be more closely associated with the lignite. This remaining water may be driven off by heating the material at a temperature of 105 degrees centigrade for a short time, but if the dried material is again exposed to the air, it will reabsorb as much water as it contained before heating.

The ash content is often high, due to the large amounts of earthy impurities present. The Alabama lignites usually contain considerable amounts of sulphur in the form of pyrite which has a corrosive action upon the metal parts of the furnaces and boilers and frequently has a tendency to form clinkers on the grate bars of the furnace. Lignite will not fuse or cake upon heating, and is thus not suitable for the manufacture of coke.

CHEMICAL PROPERTIES

The organic portion of the lignite is composed of carbon, hydrogen, nitrogen and oxygen; the heat producing elements being carbon and hydrogen of which carbon is by far the most important. The oxygen present has no real value, for all of this element required for the combustion of the fuel is obtained from the air which is drawn through the fire box by the force of the draft. The nitrogen is not affected in the process of combustion and is dissipated with the stack gases in the elemental form.

In addition to the above elements, there is always present a certain amount of impurities consisting primarily of earthy inorganic matter and the mineral pyrite, which is composed of sulphur and iron. These impurities are derived either from the mineral matter of the original vegetable accumulations, or from the sediments washed in at the time of deposition. The sulphur is oxidized to sulphur dioxide—a gas—in the process of combustion, with the liberation of a small amount of heat, while the earthy materials are left behind in the form of ash, which is composed of a number of inorganic substances, the most common of which are oxides of iron, calcium, sodium, potassium, silicon and aluminum.

For most practical purposes, the proximate method of analysis is employed for all grades of coal rather than the ultimate or elemental analysis. The proximate analysis shows the percentages of moisture, volatile matter, fixed carbon and ash, while the ultimate analysis shows the percentages of the chemical elements, carbon, hydrogen, oxygen and nitrogen and the percentage of ash present. In either case, the sulphur may or may not be determined, according to circumstances. Since the ash is not a part of the combustible matter of the lignite, it is rarely separated into its elemental constituents. The fusibility of the ash, which gives a good idea as to whether or not the fuel will form clinkers in the furnace, is often determined. In addition to the chemical analysis, the heating value of the lignite is usually determined and reported as British thermal units, per pound. A British thermal unit may be defined as the amount of heat required to raise the temperature of one pound of pure water from 62 to 63 degrees Fahrenheit. The chemical composition, heating value and fusibility of the ash of a coal furnish data for a fairly reliable estimation of its value, however, it must be remembered that the laboratory tests are made under ideal conditions, which probably cannot be duplicated in actual practice.

The following analyses of lignite and bituminous coal, taken from several sources, will serve to compare the composition of the two fuels:

<i>Locality</i>	<i>Moisture</i>	<i>Volatile Matter</i>	<i>Fixed Carbon</i>	<i>Ash</i>
Lignite from Alabama.....	36.6%	27.0%	21.5%	14.9%
Lignite from Alabama.....	35.7	31.6	29.4	3.3
Lignite from Texas.....	33.8	31.2	23.7	7.3
Lignite from Texas.....	34.7	34.3	22.7	8.3
Lignite from North Dakota.....	34.3	28.2	33.0	4.5
Lignite from North Dakota.....	35.2	25.8	30.8	8.2
Bituminous coal from Alabama.....	2.2	29.7	63.4	4.7
Bituminous coal from Alabama.....	3.4	26.9	59.0	10.7
Bituminous coal from Pennsylvania.....	2.9	33.8	53.1	10.2
Bituminous coal from Pennsylvania.....	3.4	37.5	47.6	11.5
Bituminous coal from West Virginia.....	2.8	20.8	70.3	6.2
Bituminous coal from West Virginia.....	2.6	36.8	53.4	7.2

FORMATION

Lignite is the second product in the transformation of vegetable accumulations into stone coal. The products in the order of formation, are peat, lignite, sub-bituminous, bituminous, semi-bituminous and anthracite. Since there is such an intimate relation between the peat bogs now in process of formation and the highest grades of coal, it is generally accepted that coal is formed from land plants. Peat, the first product, is formed by the accumulation and decay of grasses, leaves, sphagnum and other plants in swamps or marshy places. If the plant remains are covered with water, they will not oxidize, but slowly decompose, losing some of their water and gases with the resultant increase in the percentage of fixed carbon. At the same time these materials assume the appearance of coal.

The analyses of coals show that they contain the same chemical elements as the original vegetable accumulations, and differ from the vegetable matter in composition, primarily in the smaller percentages of water, oxygen and volatile hydrocarbons and the higher percentage of fixed carbon. The chemical composition of the ash corresponds very closely to that of the mineral matter in the original plants.

Leaves, fibers, seed and stems of plants are found in all grades of coal, and the woody texture is usually well preserved in peat and lignite. Impressions of plants or parts of plants are often found in the materials

associated with coal deposits, and stumps of trees are sometimes found standing upright in a coal seam, with the roots in the clay or shale below, which would indicate that the trees grew in a bog or swamp and the vegetable matter accumulated in the water around them. Naturally, the clay below the coal formed the surface of the land at the time of the deposition. It seems that the vegetable matter accumulated from growth in place, for the well preserved plants often found in coal beds could not have been transported by streams without losing their form. On the other hand, peat bogs are known to cover several square miles, but these areas do not by any means compare with the extensive coal deposits found in many parts of the world. Perhaps the nearest approach to coal forming conditions at the present time is found in the Great Dismal Swamp of Virginia and North Carolina.

After the peat bogs were formed, the land was submerged and the deposits were buried by a great thickness of sediments, consisting primarily of clay, sand and gravel. The resulting increase in temperature and pressure slowly converted the peat into lignite. The occurrence in certain areas of several beds of coal in the vertical section indicates that the land surface was alternately submerged and elevated to allow the accumulation of the vegetable matter and the later covering of sediments. It seems that thrust pressure, due to igneous activity or folds in the earth's crust, is much more effective in producing this change than the normal pressure, due to the weight of the overburden. Although pressure alone will convert peat into lignite, it seems that considerable heat is necessary to carry the change beyond this stage.

Thus in the normal course of events lignite occurs in the younger geological formations, Tertiary and Cretaceous, and stone coal in the older ones, primarily the Carboniferous, but this is not always the case, for, in the western part of the United States, Tertiary and Cretaceous lignites have been converted locally into bituminous or even anthracite coal by the intense heat and pressure due to igneous activity and folds in the earth's crust. In Russia, lignite is known to occur in the older Carboniferous strata.

The degree of the change from peat to anthracite seems to depend upon the intensity and duration of the temperature and pressure to which the deposits have been subjected. A very high temperature and pressure exerted for a short time would have the same effect upon the deposits as a lower pressure and temperature for a much longer time. Some writers

have claimed that these factors alone will not produce anthracite, and that in addition there must be cracks in the overlying strata to allow the free escape of the volatile matter.

MODE OF OCCURRENCE

Lignite may occur as fragments scattered throughout strata of sand, as lignitized trunks of trees, or as well defined beds. Naturally, the fragments and logs have no economic value, but may be of scientific interest. Exposures are most commonly found in the beds and banks of streams where the sands and clays have been carried away by the flood waters, however, occasional outcrops are encountered in gullies, ravines and cuts. Lignite rarely appears at the surface in level or gently rolling areas as it is usually covered with sand, clay and gravel from the overlying formations. Except for an occasional ledge of consolidated marl, the materials associated with the deposits are primarily sand and clay. The terrace sands and clays of a much later geological age form a mantle over the greater part of the area, which helps to obscure the beds.

Springs are usually good indications of outcrops. Since the lignite beds and the associated clays are impervious to water, the descending ground waters striking these beds are arrested in their downward course, and deflected along the dip of the strata until they find an outlet at some lower place where the beds come to the surface. Lignite is frequently struck in digging or drilling wells and in making cuts for road beds.

No shale or sandstone of any importance as a roof is found above the lignite seams of the State, but in some cases a few inches of sand immediately above the beds has been converted into a hard ledge of ferruginous sandstone by the deposition of ferric oxide cement from the impregnated ground waters. The ground waters descending through the overlying formations become impregnated with soluble compounds of ferrous iron and when arrested in their downward course by the impervious beds of lignite, the soluble compounds are oxidized and deposited as ferric oxide in the space between the sand grains forming a ferruginous sandstone. Calcium carbonate may also be deposited in a similar manner and serve as a cementing material in forming consolidated ledges above the seams.

Immediately underlying the beds is usually found a stratum of dark colored clay of variable thickness, which is frequently very lignitic and

deeply colored by this material. Rarely the total thickness of the clay is exposed, due to the fact that the outcrops generally appear in the beds and banks of streams. The associated sands are sometimes carbonaceous in character.

THICKNESS, CHARACTER AND QUALITY OF THE BEDS

The thickest bed that the writer has seen is exposed in a cut along the Alabama, Tennessee and North Railroad about five miles south of York, Sumter County. Here the lignite is twelve feet thick and except for the upper two feet is of excellent quality. In Marengo and Wilcox counties exposures from four to seven feet are not unusual, while thicknesses from one to three feet are frequently encountered throughout the entire lignite area. At many places the exposures occur in the beds of streams and the total thickness has not been determined. Beds much thicker than those described in this bulletin have been reported, but the writer has not been able to verify any of them, and for this reason they have not been included.

The casual or inexperienced observer is often misled as to the thickness of the beds, due to the fact that the associated clays and sands are frequently colored dark brown to black, with lignitic material and thus very easily mistaken for the lignite. The beds often grade into lignitic sands and clays, which sometimes makes the dividing line difficult to establish and it is, therefore, frequently advisable to be reluctant in taking reported thickness as correct without verification, although they may have been given in good faith. The beds often contain considerable amounts of pyrite, which is the source of most of the sulphur and iron.

Except in Wilcox and Marengo counties, the thickness and areal extent of the lignite beds are by no means certain. As a general rule, the thickness of the beds changes with remarkable rapidity, often thinning to a few inches, or playing out entirely in a very short distance, and due to this condition, no reliable estimate of the areal extent and available tonnage of the lignite in Alabama can be given until a great deal more work has been done.

It would seem that the lignite was originally laid down in relatively small marshes or swamps and for this reason, the deposits generally have a lenticular shape and limited areal extent. This characteristic is well ex-

hibited at the outcrop along the highway about five miles north of Thomasville, Clarke County, where the bed can be seen to play out in each direction.

Due to the uncertainty of the lignite beds and the limited number of outcrops, it would not be advisable to invest large sums of money in the development of an area until the thickness, areal extent, and quality of the beds have been determined. This can best be accomplished by putting down test holes at regular intervals over the territory. In a great many cases, this can be accomplished by boring with small hand augurs or by digging test pits. Core drills are of course most satisfactory for drilling comparatively deep holes or for drilling through hard strata, and since the cores may be taken out intact and examined, they furnish a complete section of the materials encountered.

In boring with small hand drills or augurs, the cuttings should be carefully examined so as not to mistake the dark colored and lignitic clays for workable lignite. The beds frequently contain clay partings which should be taken into account in determining their workable thickness. Frequently chemical analyses of the drillings are necessary to determine the quality of the lignite.

Having determined the thickness, areal extent and quality of the beds in a given area, the available tonnage of the fuel may be easily calculated. Since the average specific gravity of lignite is approximately 1.3, one cubic foot of the solid material weighs about 81 pounds. A bed one foot thick and one acre in areal extent would occupy 42,902 cubic feet and would contain approximately 3,475,000 pounds or 1787 tons of lignite. Naturally, there is some loss in mining and all the material cannot be extracted, but assuming an 80 per cent recovery, which is a fair average, one acre foot of lignite will yield approximately 1430 tons. With this as a unit, the available tonnage in any area may be determined by simple multiplication.

It must, however, be borne in mind that uniformity and consistency of the beds, so desirable for economic mining operations are frequently lacking in the lignite area of the State.

PLATE 1



Outline map of Alabama showing areal extent of outcrop of the important lignite bearing formations.

GEOLOGY

The lignite deposits of Alabama are restricted to the younger geological formations of the Cretaceous and Tertiary eras in the southern and western parts of the State. By far the most important deposits occur in the Wilcox group of formations, known as the lignitic by the older writers, which belong to the Eocene period of the Tertiary era. This area consists of a narrow and irregular strip of territory about twenty-five miles wide, which extends a little north of west and south of east across the State, and includes the greater part of Wilcox, Butler and Crenshaw counties, the southern part of Barbour, Pike, Marengo and Sumter counties, and the northern part of Henry, Dale, Coffee, Monroe, Clarke, Choctaw, Covington and Conecuh counties. The Wilcox group consists of four formations, in order of deposition, the Nanafalia, Tuscahoma, Bashi and Hatchetigbee. The materials of this group consist primarily of gray and orange sands and gray, brown and black clays in variable proportions with strata of greensand, consolidated marl, shell beds, aluminous sandstone and lignite. The maximum thickness of this group of formations in the vicinity of Alabama and Tombigbee Rivers is about eight hundred feet. The strata have a normal dip to the southwest of thirty to fifty feet to the mile.

These formations do not contain any important resistant beds which would exert a decided influence upon the topography, and the area of their outcrop is characterized by rounded hills of low relief, which are formed by the natural process of erosion. The Nanafalia formation contains beds of "pseudo-buhrstone," and indurated marl, which are fairly resistant and locally produce minor north facing escarpments.

The lignite beds are thicker and more numerous in the western part of the State, in the vicinity of Tombigbee River, while east of the Alabama River they become, as a rule, inconspicuous. The individual seams have no well marked characteristics by which they can be recognized from place to place, although certain of the thicker ones can be traced to some extent by their relation to the associated marl beds. Because of this condition, it is very difficult to trace the lignite seams, so as to determine their areal extent.

The thickest and most consistent seam, known as the Coal Bluff, occurs near the base of the Nanafalia formation, and about eighty feet below the *Ostrea thirsae* beds. This bed is four feet thick at Coal Bluff on the

PLATE 2



Outline map of Alabama showing areal extent of outcrop of the minor lignite bearing formations.

Alabama River, in Wilcox County, and seven feet thick in the banks of Landrums Creek, near the Tombigbee River in Marengo County. It appears at many places in Wilcox and Marengo counties and except where it has been removed by erosion, seems to be continuous over the greater part of the area, and holds an average thickness of four to seven feet. Outside of this area the lignite beds are relatively thin and do not seem to be very extensive.

In the western part of the State the Nanafalia formation exhibits three characteristic divisions. The upper member, which consists of about forty feet of indurated gray clay and sandy clay with some greensand, resembles the buhrstone of the Tallahatta formation, and is sometimes referred to as the "pseudo-buhrstone." The middle division is made up of seventy-five to eighty feet of white, yellow and red sands with alternating beds of glauconitic sand, both of which are literally packed with *Ostrea thirsae* shells. The lowermost member, which follows the shell beds, consists of about eighty feet of sandy clays and crossbedded sands grading into greensand near the base, with a seam of lignite from four to seven feet thick, forming the basal bed of the formation.

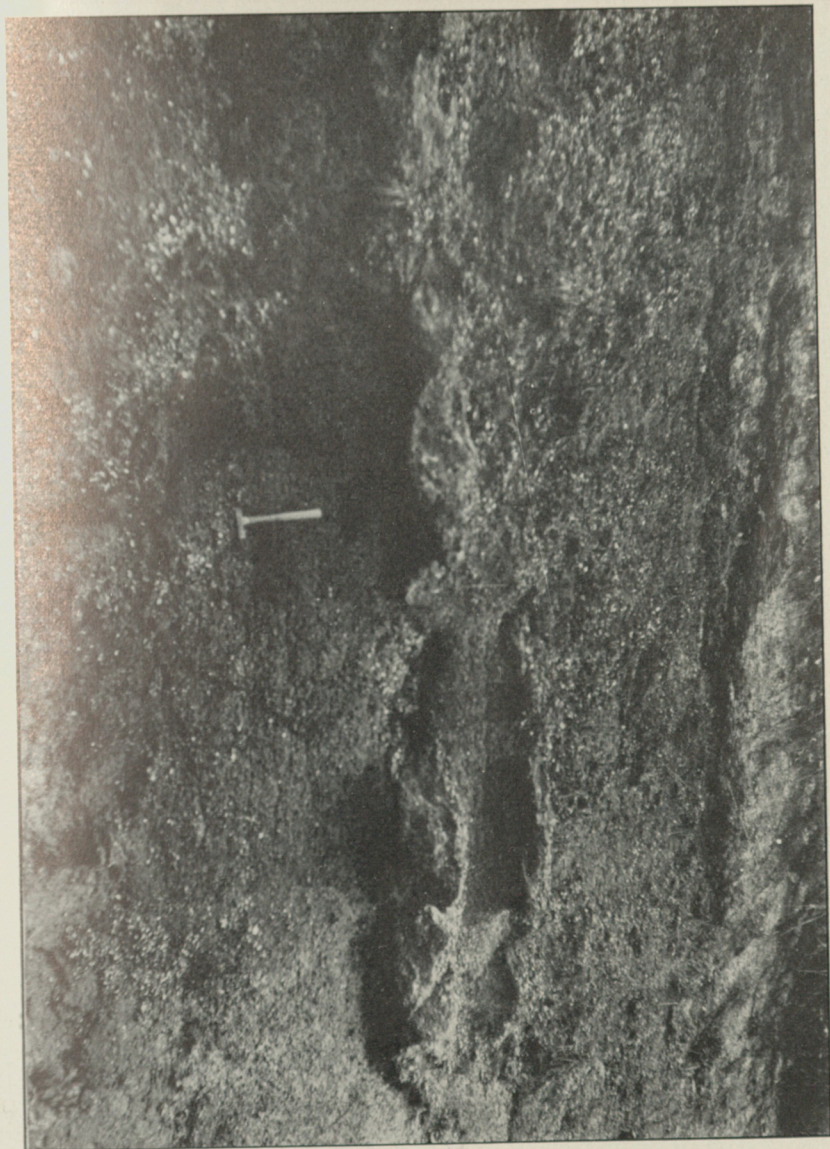
The next most important lignite bearing formation is the Bashi, which is next above the Nanafalia in the geological section. This formation consists of a bed of greenish glauconitic marl at the top, from 13 to 20 feet thick, with about twenty-five feet of laminated sand and clay below which contains four or five thin seams of lignite, none of which are normally more than one foot thick. Below the laminated sand and clay member lies from thirty-five to forty feet of yellowish cross-bedded sand, with a seam of lignite two feet thick at the base. Locally, certain of these seams thicken until they attain a maximum of three to five feet.

Lignite occurs in both the Tusahoma and the Hatchetigbee formations of this group, but these seams are not consistent either in thickness, quality or areal extent, and do not offer much promise.

The following sections adapted from Cooke¹ show the general character of the materials associated with the lignite deposits of Alabama:

¹ Cooke, C. W.: Geology of Alabama, The Cenozoic Formations, Special Report No. 14, Geological Survey of Alabama, 1926.

PLATE 3



Typical exposure of the *Ostrea thirsae* member of the Nanafalia formation, along the highway about one mile south of Kimbrough, Wilcox County.

Composite Section of the Nanafalia Formation, Wilcox County.

	Feet
Blue laminated jointed clay, weathering to tough yellow clay	42
Hard calcareous fossiliferous sandy claystone	2
Blue laminated to jointed clay, cream colored on dry exposures	6
Sandy fossiliferous calcareous claystone	5
Blue kaolin-like clay, conchoidal fracture	25
Hard glauconitic calcareous claystone with fossils	3
Blue jointed clay, with a few sandy layers	6
Hard glauconitic calcareous claystone with fossils	2
Blue kaolin-like clay, conchoidal fracture	10
Hard sandy bed containing much glauconite that is altering to limonite	6
Unconsolidated white to yellow sand	5
Laminated sand and clay	9
Hard highly fossiliferous, glauconitic clay; upper limit of <i>Ostrea thirsae</i>	2
Glauconitic sandy marl with large numbers of <i>Ostrea thirsae</i>	8
Laminated blue sandy clay	5
Glauconitic <i>Ostrea thirsae</i> marl	30
Glauconitic sand, no fossils	3
White to yellow cross-bedded massive sands with clay lenses	20
Black laminated carbonaceous clay	5
Unconsolidated sand with indurated nodules	8
Black laminated clay	8
Unconsolidated glauconitic sand with boulder-like nodules	8
Black laminated clays	10
Sand with boulder-like nodules and hard ledges	15
Lignite	4
Lignitic clay	2½

Section of Tuscaloosa formation exposed at Bell's Landing, Alabama River.

	Feet
Fine olive drab glauconitic micaceous sand	20
Thin-bedded to laminated gray sand and clay	37
Bell's Landing marl member; fine, greenish gray glauconitic sand loaded with shells; three large species of <i>Turritella</i> , very abundant; upper part irregularly indurated into boulder-like masses	8
Very fine, loose, gray micaceous sand	5
Very fine, gray, compact sand with contorted inclusions, of similar material at base; somewhat micaceous; contains comminuted plants	6
Fine, gray, laminated, somewhat micaceous sand at base, contains comminuted plants; to low water	30

Section of Bashi formation at Yellow Bluff, Alabama River

	Feet
Greensand marl, with indurated rounded masses above the loose marl below; fossiliferous; about	6
Blue clay	1
Gray sandy clay with a slight tinge of purple, holding four or five thin seams of lignite, each one foot thick or less; obscured by landslides	40-50
Reddish cross-bedded sands	20
Lignitic clay and lignite	2

Section of Hatchetigbee formation at Hatchetigbee Bluff, Tombigbee River.

	<i>Feet</i>
Sandy clays of brown, yellowish and reddish colors interstratified; these are dark blue when moist but of lighter color when dry.....	15-20
Heavy bedded dark-brown clays, somewhat like bed above but of darker color when dry.....	10
Yellowish glauconitic marl; this bed shows a tendency to form at intervals hard concretionary ledges, which on weathering break off and roll down the bluff and are piled in great numbers at its base; some of these boulders have a nucleus of shells which, however, are not usually well preserved.....	2- 3
Purplish brown sandy clays in the middle of which is a projecting ledge of dark clays, which are harder but which break up into small fragments upon drying and upon exposure to weather.....	15
Yellowish-gray sands, striped with thin streaks of brown sandy clay; these sands at intervals along the bluff form indurated concretionary rounded masses.....	5- 6
Bluish brown sandy clay marl containing many shells; the upper part more fossiliferous.....	5- 6
Laminated grayish sands interstratified with thin beds of brown or black lignitic clay; these sands form rounded concretionary masses which project from face of bluff.....	4
Heavy bedded gray sandy clays, with streaks of brown clay.....	8
Reddish sandy marl, highly fossiliferous, forming concretionary boulders, remarkable for the great number of <i>Venericardia planicosta</i> but containing also <i>Plejona tuomeyi</i> and other forms.....	4- 5
Dark gray to brown sandy clay to water.....	15

"The Wilcox epoch was characterized by the shoaling of the water of the Clayton sea, over the submarine terrace, a refreshing of these waters near the shores and a consequent destruction of marine organisms, and an extension of the land flora and a commingling of its remains with the littoral deposit. The altitude of the land with respect to the sea was generally persistent through the Wilcox epoch, but depressions went on apparently *pari passu* with sedimentations and there were occasional oscillations and consequent incursions of the sea upon the land, notably those represented by the Bashi and Nanafalia marls and excursions of the terrestrial flora upon the coastal marshes.

"From the initiation of the Tuscaloosa epoch to the close of the Wilcox, the off-shore sediments appear to have been pushed farther and farther into the sea, and the depression accompanying the sedimentation appears to have been uniform throughout the area over which the deposits are now exposed, but the Wilcox epoch was apparently terminated by a depression (perhaps due to its own weight) of the margin of the subaqueous sheet thus formed, and a consequent increase of depth of the off-shore waters and in violence of waves and currents. These conditions

induced increased heterogeneity and coarseness of deposits, the invasion of the deep sea fauna and the entombment of its remains in littoral deposits."¹

Although the Wilcox is the primary lignite bearing formation in Alabama, these beds are also found to some extent in other geological horizons. The Tuscaloosa formation of upper Cretaceous age contains lignite both in well defined beds and in pockets. These beds have their maximum development in Lamar County, in the western part of the State where they show a thickness of three to four feet. This formation consists of irregularly-bedded sands, clays and gravel, which in the western part of the State reaches a maximum thickness of one thousand feet. The color of the materials ranges from light buff and gray to dark gray and dark green, with many beds of yellow, purple, red and brown. The gravel occurs primarily in the lower beds of the formation, with quartz pebbles predominating in the eastern part of the State, and chert pebbles in the western part. The surface material is usually colored dark red by ferric oxide, which is produced by oxidation of the soluble ferrous compounds.

The areal extent of this formation is characterized by steeply rolling and hilly uplands with many deep gullies and ravines. The larger streams have planed down this upland along their courses forming broad valleys which frequently attain a width of several miles.

During this period (Tuscaloosa) it seems probable that the sea bottom was slowly sinking about as fast as it was built up by the sediments brought down from the land area. Logs, leaves and plants were carried down by the streams, buried in the sediments and preserved so that we now find them in the form of leaf impressions, lignitized trunks of trees and beds of lignite. Deposited in this manner, it would be natural to expect the lignite beds to contain a considerable proportion of earthy impurities, which were deposited along with the carbonaceous material.

Occasional pockets and logs of lignite are found in the Eutaw formation of Cretaceous age, but no well defined beds have been reported. This formation succeeds the Tuscaloosa in the geological column and is composed primarily of glauconitic sand, with irregular beds of green to dark gray clays.

Lignite also occurs in the Sucarnoochee and Naheola formations of the Midway group, which also belongs to the Eocene period of the Tertiary

¹ Smith, Eugene A., Coastal Plain of Alabama, *Geological Survey of Alabama*, 1894.

era, but these deposits as a general rule do not appear to be very important. In Sumter County a well defined seam of lignite occurs in the Sucarnoochee formation near the upper limit of the black clays.

A detailed description of the geology of the lignite area of the State may be had from the report on the Geology of Alabama, and the accompanying geological map, issued by the Geological Survey of Alabama, 1926.

STRATIGRAPHY

The following table gives the names of the formations into which the strata of the coastal plain of Alabama have been divided together with their general lithologic character and thickness. The lignite bearing formations have been described in considerable detail in the preceding chapter but in order to present the character of the related formations the stratigraphic section is included. Since the formations vary considerably from east to west and the lignite beds are thicker and more numerous in west Alabama, the table is adapted from this part of the State.

Lignite occurs in Alabama in formations ranging from the Tuscaloosa of Cretaceous age to the Hatchetigbee of Tertiary age, although it does not appear in all the intervening formations.

No occurrence of this material has been reported in formations younger than the Hatchetigbee, in Alabama.

STRATIGRAPHIC SECTION OF THE FORMATIONS REPRESENTED IN THE QUATERNARY, TERTIARY AND CRETACEOUS STRATA OF WESTERN ALABAMA

<i>System.</i>	<i>Series.</i>	<i>Group.</i>	<i>Formation.</i>	<i>Thickness in Feet.</i>	<i>Lithologic Character.</i>
TERTIARY	Recent.		Alluvium.		Sand, clay and gravel.
			Terrace deposits.		Sand, clay, gravel and loam.
	Pleistocene.		Citronelle.	0-100	Gravel, sand and clay, red and orange colors.
			Hattiesburg clay. Catahoula sandstone.	0-200	White, pink and gray sands and clay. Locally indurated. Light gray sands and sandstone; greenish gray clays.
	Miocene.		Byram marl.	25- 35	Light gray and cream colored soft marl and greenish clays; impure limestone.
			Glendon limestone.	12- 15	Hard crystalline cavernous limestone, "Horse-bone."
	OLIGOCENE		Marianna limestone.	55- 75	White to cream colored soft porous limestone, "Chimney rock."
			Red Bluff clays.	20- 40	Yellowish to greenish plastic clays, containing crystals of gypsum; glauconitic marls and marly limestone in upper part.
	EOCENE	Jackson.	Jackson.	80-115	Plastic gray and green clays; indurated marl and medium fine grained yellow sand below, with bluish green clay at base.
			Gosport.	0- 35	Greensand and indurated glauconitic, sandy marl; very fossiliferous; weathers to yellow or red colors.
		CLAIBORNE	Lisbon.	40-165	Calcareous sands and clays with beds of indurated marl and oyster shells; glauconitic sands, very fossiliferous, weathering red.

STRATIGRAPHIC SECTION OF THE FORMATIONS REPRESENTED IN THE QUATERNARY, TERTIARY AND CRETACEOUS STRATA OF WESTERN ALABAMA—(Continued)

28

GEOLOGICAL SURVEY OF ALABAMA

System.	Series.	Group.	Formation.	Thickness in Feet.	Lithologic Character.
TERTIARY	EOCENE	WILCOX	Claiborne (Cont.)	20-200	Claystone, sandstone, and argillaceous sandstone, light gray to green, very siliceous; generally contains but few fossils; glauconitic in part.
			Hatchetigbee.	200-300	Sands and sandy clays, light gray to green on fresh exposure, but weathers to yellow and brown. Lignitic in part and contains numerous beds of marine fossils.
			Bashi.	80-125	Fossiliferous greensand marl at top; laminated sands and clays with thin seams of lignite below; crossbedded yellowish sand with seam of lignite two feet thick at base.
			Tuscahoma.	140-200	Gray sands, sandy clays and greensand with two very fossiliferous marl beds. Lignitic in part.
			Nanafalia.	200-250	Upper division consists of indurated gray clay and sandy clay with some greensand, "Pseudobuhrstone." Middle member; yellow and red sands with alternating beds of greensand, packed with <i>Ostrea thirsae</i> shells. Lower member; cross bedded sands and sandy clays grading into greensand below with bed of lignite at base.
		MIDWAY	Naheola.	150-200	Buff and pink sands, glauconitic beds and dark gray sandy clays. Marine fossils in lower part. Lignitic in part.
			Sucarnoochee.	100-200	Tough dark gray to black clay with conchoidal fracture. Grows calcareous toward base. Contains beds of lignite.
			Clayton limestone.	0-25	White limestone and white to yellow micaceous sands. Shows all gradations from hard limestone to sandy limestone, calcareous sand and loose sand.

STRATIGRAPHIC SECTION OF THE FORMATIONS REPRESENTED IN THE QUATERNARY, TERTIARY AND
CRETACEOUS STRATA OF WESTERN ALABAMA—(Continued)

<i>System.</i>	<i>Series.</i>	<i>Group.</i>	<i>Formation.</i>	<i>Thickness in Feet.</i>	<i>Lithologic Character.</i>
CRETACEOUS	UPPER CRETACEOUS		Ripley.	0-150	Marine sands and clays, sandy clays and clayey sands, indurated, calcareous sandstone and sandy limestone. In part glauconitic.
			Selma chalk.	900-1000	Grayish to bluish chalk, chalky limestone and thin beds of pure limestone. In part clayey, in part sandy.
			Eutaw.	400-500	Glauconitic fine to medium grained micaceous sands of shallow marine depositions. Lower part contains beds of gray to black lignitic clays. Sands in part massive, in part cross-bedded. Contains fragments of lignite.
			Tuscaloosa.	900-1000	Irregularly bedded, non-marine, clays, sands and gravel; light buff and gray to dark gray and green color, weathering red; contains lignite as fragments and as well defined beds; gravel occurs primarily in lower beds as chert pebbles.

DESCRIPTION OF OUTCROPS

Descriptions of the most important exposures of lignite in Alabama are given below, grouped alphabetically by counties. In most cases the geological section in which the lignite occurs is given.

Barbour County.—Lignite outcrops in the bank of a small stream about one-half mile southeast of Bakerhill, Barbour County. This bed has an unusually steep dip to the southeast of about fifteen degrees, and has a heavy cover of sand and clay. The stratigraphic section is given below:

<i>Character of Materials</i>	<i>Feet</i>
Clay and sand to top of bluff	10
Lignite	4
Blue clay	2
White and purple clays	5

Lignite outcrops in Sec. 25, T. 8 N., R. 23 E., Barbour County.

<i>Character of Materials</i>	<i>Feet</i>
Aluminous sandstone	10
Light yellow sand becoming red with depth	30
Badly weathered lignite	3
White sand	2

This outcrop is in the Nanafalia formation.

Choctaw County.—Lignite outcrops in a railroad cut in the N.W. $\frac{1}{4}$ of Sec. 35, T. 14 N., R. 4 W., Choctaw County.

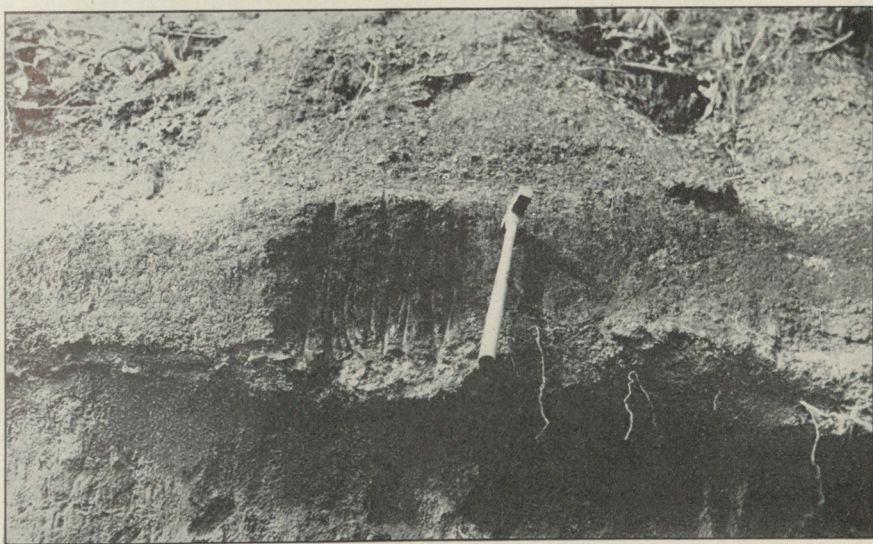
<i>Character of Materials</i>	<i>Feet</i>
Brown sandy clay	10
Purple clay	6
Lignite	2
Blue clay	1

This outcrop is in the Hatchetigbee formation.

PLATE 4



A.—Lignite outcrop in the bed of a small stream one-half mile southeast of Bakerhill, Barbour County.



B.—Lignite outcrop along the highway about two miles east of Magnolia, Marengo County.

Lignite shows in another railroad cut about seventy yards southeast of the above place:

<i>Character of Materials</i>	<i>Feet</i>
Brown sandy clay.....	6
Purple clay.....	3
Lignite	3
Blue clay.....	3

This outcrop is also in the Hatchetigbee formation.

Lignite outcrops in the bed of Oaktuppah Creek, causing a waterfall in the S.E. $\frac{1}{4}$ of Sec. 18, T. 13 N., R. 4 W., Choctaw County:

<i>Character of Materials</i>	<i>Feet</i>
Thin bedded consolidated sands.....	4
Brown clay.....	3
Purple clay.....	3
Lignite	2
Gray and purple sandy clay.....	3

This outcrop appears to be in the Hatchetigbee formation.

Lignite outcrops in a gully about one-fourth mile east of Riderwood in the S.W. $\frac{1}{4}$ of the N.E. $\frac{1}{4}$ of Sec. 6, T. 13 N., R. 3 W., Choctaw County:

<i>Character of Materials</i>	<i>Feet</i>
Consolidated marl.....	5
Brown clay.....	12
Lignite	1
Unconformable mottled clay.....	6

This outcrop is in the Bashi formation.

A seam of lignite five feet thick was struck in the Cullom Springs well, Sec. 29, T. 9 N., R. 2 W., Choctaw County, at a depth of 337 feet. This seam is in the Tusahoma formation.

Clarke County.—Lignite outcrops in a cut along the Thomasville and Linden highway five miles north of Thomasville, Clarke County:

<i>Character of Materials</i>	<i>Feet</i>
Brown mottled clay, laminated	6
Lignite	3
Blue clay	4

This outcrop is in the Bashi formation.

Lignite outcrops in the bed of Bashi Creek, about one hundred yards below the entrance of Tallahatta Creek, in Sec. 8, T. 11 N., R. 1 E., Clarke County:

<i>Character of Materials</i>	<i>Feet</i>
Blue sandy clay	15
Lignite to bed of creek	4

The total thickness of the seam was not exposed. This outcrop is in the Bashi formation.

Lignite outcrops in a cut along the Southern Railroad just north of Thomasville, Clarke County. This bed seems to be lenticular and it contains a considerable amount of clay:

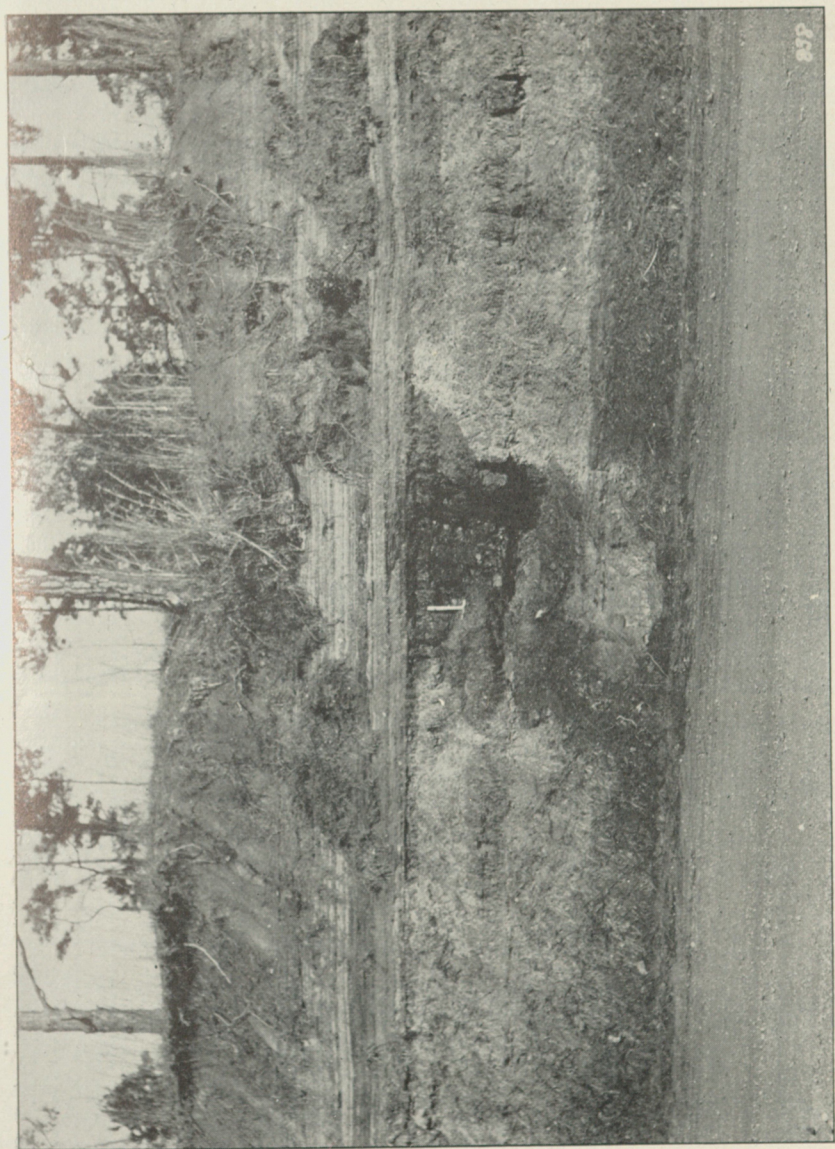
<i>Character of Materials</i>	<i>Feet</i>
Gray and yellow laminated clay	12
Lignite	2
Blue laminated clay	3

This lignite belongs in the Hatchetigbee formation.

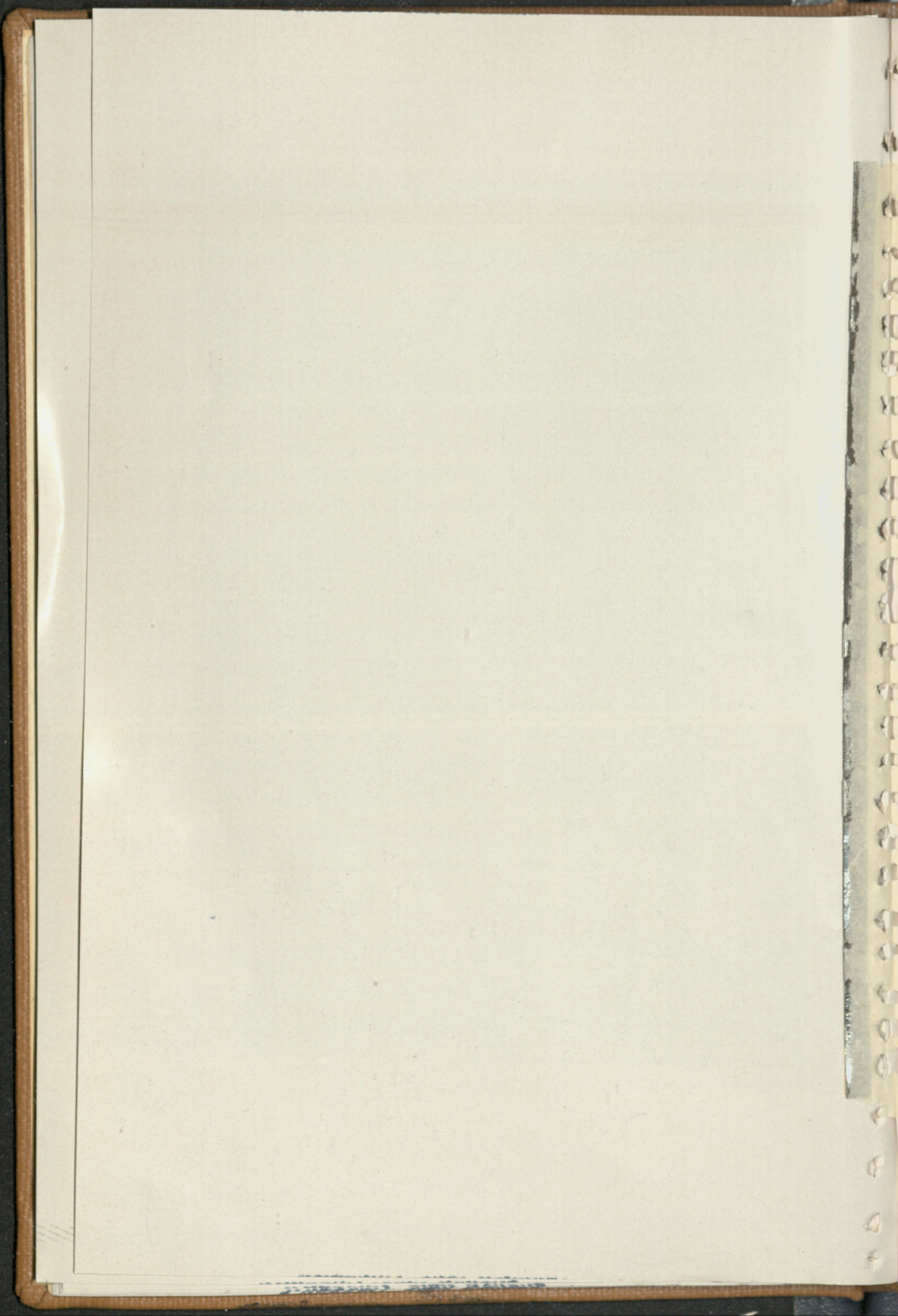
Coffee County.—Lignite outcrops in the bed of Sweetwater Creek about one mile north of Bluff Springs Church, near the place where the old road from Troy to Elba by way of County Line crosses this creek. The total thickness of the lignite was not determined but a thickness of four feet could be seen to the creek bed. The overburden consists of about five feet of light colored sands, which gradually thickens away from the creek.

The outcrop is apparently in the Nanafalia formation.

PLATE 5



Exposure of lignite in a cut along the highway five miles north of Thomasville, Clarke County.



Lamar County.—Lignite outcrops in a small creek on the Wheeler place, practically on the State line in Sec. 36, T. 16 S., R. 17 W. This bed of lignite contains a considerable proportion of clayey impurities and the mineral pyrite. It is three feet thick; is overlain with yellow micaceous sand and gravel, and is underlain with five feet of blue clay, which contains some carbonaceous material. The outcrop occurs in the Tuscaloosa formation. Other outcrops appear in the beds of Claybank and Yellow creeks in the extreme western part of the county.

Marengo County.—Lignite outcrops in the banks of Landrums Creek, near Nanafalia, Marengo County, in the following stratigraphic section:

<i>Character of Materials</i>	<i>Feet</i>
Dark micaceous glauconitic sand.....	15
Lignite	7
Dark gray sandy clay.....	2

This outcrop is in the Nanafalia formation and is the Coal Bluff seam.

Lignite outcrops in the banks of Landrums Creek in Sec. 23, T. 14 N., R. 1 E., Marengo County:

<i>Character of Materials</i>	<i>Feet</i>
Green and yellow sand.....	12
Lignite	7
Blue clay.....	3

This lignite belongs in the Nanafalia formation and is the Coal Bluff seam.

Lignite outcrops at Pickens Landing on the Tombigbee River, Marengo County:

<i>Character of Materials</i>	<i>Feet</i>
Gray laminated sandy clays.....	10
Lignite	1½
Blue clayey sands.....	7
Lignite	2
Gray sandy clay to water level.....	2

This lignite occurs in the Bashi formation.

A thin seam of lignite about one foot thick outcrops at several places along the highway one to two miles east of Magnolia, Marengo County.

A number of water wells drilled on the site of the new town of Magnolia in Sec. 4, T. 13 N., R. 4 E., in this county struck a bed of lignite six feet thick. The wells were drilled on the side of a hill and the depth at which the lignite was struck ranged from eleven to thirty-four feet, depending upon the elevation of the surface at place where the drilling commenced. This is evidently the Coal Bluff seam of lignite, which belongs in the Nanafalia formation.

Monroe County.—Lignite outcrops in the bed of Little Flat Creek, near its confluence with Flat Creek in Sec. 6, T. 8 N., R. 8 E., Monroe County:

<i>Character of Materials</i>	<i>Feet</i>
Green and yellow sand	5
Lignite to creek bed	3

The total thickness of the seam was not exposed. This lignite occurs in the Bashi formation, and is of excellent quality.

About one-fourth mile farther up the creek lignite appears in its bed in the same formation. As shown in the following stratigraphic section, the lignite is overlain by a stratum of consolidated marl about four feet thick:

<i>Character of Materials</i>	<i>Feet</i>
Light colored sand to top of bluff	5
Consolidated marl	4
Fossiliferous greensand	2
Lignite to creek bed	4

The total thickness of the lignite was not exposed.

About one-fourth mile farther up the creek lignite shows along its bed in the same formation and in a similar section:

<i>Character of Materials</i>	<i>Feet</i>
Consolidated marl	4
Fossiliferous greensand	2
Lignite to bed of creek	4

PLATE 6



Exposure of lignite in a bluff on Landrums Creek, Sec. 23, T. 14 N., R. 1 E., Marengo County.

The total thickness of the seam was not exposed.

Lignite shows in the bed of a small stream in Sec. 23, T. 10 N., R. 7 E., Monroe County. The thickness of the lignite is four feet with a six-inch clay parting one foot from the bottom. This outcrop is in the Tuscahoma formation.

Lignite outcrops at Bell's Landing on the Alabama River, Monroe County:

<i>Character of Materials</i>	<i>Feet</i>
Yellow crossbedded sands	15
Lignite	2
Laminated sandy clays with a few boulder-like concretions..	10
Gray and sandy clays, laminated.....	30
Greensand marl	8
Dark gray laminated sandy clays.....	25

This seam of lignite is in the Tuscahoma formation.

Lignite outcrops in the bed of a small stream in Sec. 31, T. 10 N., R. 7 E., Monroe County:

<i>Character of Materials</i>	<i>Feet</i>
Greensand with Tuscahoma fossils.....	3
Lignite to bed of creek.....	4

This occurrence is in the Tuscahoma formation.

Lignite also crops out in the bed of a tributary of the above creek in Section 32, T. 10 N., R. 7 E., Monroe County. This seam is three feet thick, and is overlain by about three feet of greensand, which contains Tuscahoma fossils.

Lignite outcrops in the bed of a small stream in Sec. 29, T. 10 N., R. 7 E., Monroe County. This seam is about two feet thick to the creek bed, and is overlain by three feet of greensand, containing Tuscahoma fossils.

Pike County.—Lignite outcrops in the bank of Conecuh River in Sec. 21, T. 8, N. R. 19, E., Pike County:

<i>Character of Materials</i>	<i>Feet</i>
Yellow and purple sandy clays, interlaminated with micaceous sand	10
Lignite	3
Purple sand	20
Brown micaceous sand	2

This outcrop is in the Nanafalia formation.

Lignite outcrops in the bed of Deer Creek about three miles southeast of Glenwood, Sec. 32, T. 8 N., R. 19 E., Pike County. The outcrop is in Pike County, although Glenwood is in Conecuh County.

<i>Character of Materials</i>	<i>Feet</i>
Sand and clay	20
Blue clay with <i>Ostrea thirsae</i> shells	6
Lignite to bed of creek	4

The total thickness of the lignite was not determined. This bed belongs in the Nanafalia formation and is the Coal Bluff seam of lignite.

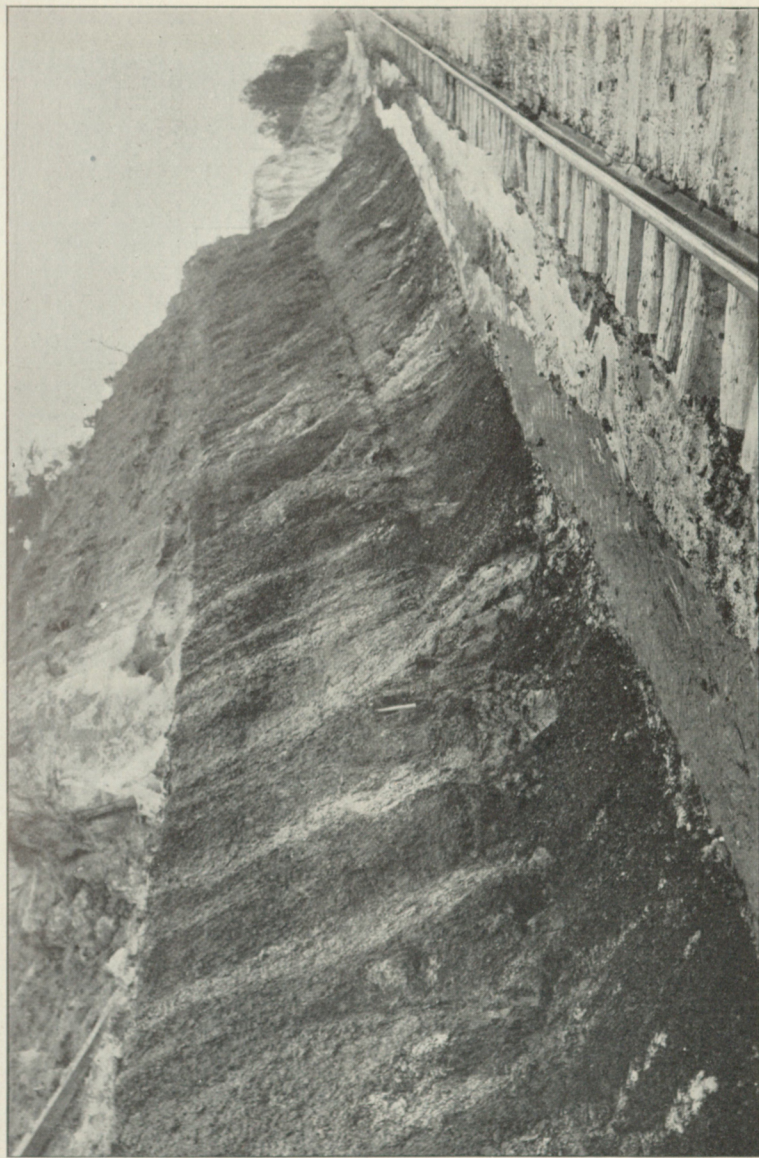
Lignite was reported to be six feet thick in a well in Mr. J. W. Jackson's yard about one-half mile north of the above place. A thin seam of badly weathered lignite eighteen inches thick crops out in the road about one mile southeast of Mr. Jackson's house.

The above lignites are also in the Nanafalia formation.

Sumter County.—Lignite outcrops in a deep cut along the Alabama, Tennessee and Northern Railroad about five miles south of York, Sumter County. This bed is twelve feet thick but the upper two feet are of poor quality. It is exposed for a distance of about 200 yards along the track and shows practically no variation in thickness. The north end of the exposure seems to be cut off by a fault. This outcrop is in the Sucarnoochee formation, and exhibits the following section:

<i>Character of Materials</i>	<i>Feet</i>
Yellow and orange sand	15
Lignite	12
Blue clay, massive	7

PLATE 7



Exposure of lignite in a cut along the Alabama, Tennessee and Northern Railroad five miles south of York, Sumter County.

Tuscaloosa County.—Fragments of lignitized stems and trunks of trees show in the banks of the Warrior River at Saunder's Ferry, and also in the bluffs along Big Sandy Creek in the southern part of the county. The lignite at both of these localities occurs in the Tuscaloosa formation.

Wilcox County.—Lignite outcrops at Coal Bluff on the Alabama River, Wilcox County. This is a typical exposure of the Nanafalia lignite and the bed takes its name from this bluff. The stratigraphic section at Coal Bluff is given below:

<i>Character of Materials</i>	<i>Feet</i>
Greensand	8
Lignite	4
Compact, gray, sandy clay	10

Lignite is exposed in the upper part of Yellow Bluff on the Alabama River, Wilcox County:

<i>Character of Materials</i>	<i>Feet</i>
Greensand marl	6
Blue clay	1
Gray sandy clay marl, with four to five thin seams of lignite, each about one foot thick	45
Reddish cross-bedded sand	20
Lignite grading into lignitic clay	2
Reddish sands	15
Laminated sandy clays	25
Greensand marl with a parting of sandy clay one foot from the top	8

These seams are in the Bashi formation.

Lignite outcrops at Peeble's Landing, on the Alabama River, Wilcox County:

<i>Character of Materials</i>	<i>Feet</i>
Yellow sand	2
Lignite	2
Reddish sand	10
Gray clays and sand, interstratified	30

Greensand marl, forming boulders.....	3
Dark gray sandy clays, laminated	25
Terrace deposits to water level	20

This seam is in the Tuscahoma formation.

Lignite appears along the bed of Pursley Creek in Sec. 2, T. 11 N., R. 7 E., Wilcox County, but the total thickness of the bed is not exposed.

<i>Character of Materials</i>	<i>Feet</i>
Gray sandy clay to top of bluff	6
Lignite to bed of creek	2

This lignite occurs in the Nanafalia formation.

Lignite outcrops in the bed of a small stream near Bellview, Sec. 4, T. 10 N., R. 7 E., Wilcox County. About two feet of lignite shows above the creek bed, but the total thickness of the seam was not exposed.

The Coal Bluff seam of lignite of the Nanafalia formation outcrops in the bed of Turkey Creek, near the railroad trestle, about one mile south of Kimbrough, Wilcox County. The exposed thickness at this locality was four feet.

ANALYSES OF LIGNITE BY COUNTIES

The following analyses, made in the laboratory of the Geological Survey of Alabama are typical of the lignites found in the State. Most of the samples were taken from outcrops and in some cases the lignite may have been slightly weathered, although an effort was made to collect representative samples.

Barbour County.—Analysis of lignite from near Bakerhill, Barbour County:

	<i>Moisture as Received</i>	<i>Calculated to Dry Basis</i>
Moisture	10.7%	
Volatile matter.....	34.3	38.4%
Fixed carbon	26.8	30.0
Ash	28.2	31.6

Analysis of lignite from the bed of a small creek about one mile south-east of Bakerhill, Barbour County:

	<i>Moisture as Received</i>	<i>Calculated to Dry Basis</i>
Moisture	24.0%	
Volatile matter	33.7	44.4%
Fixed carbon	19.0	25.0
Ash	23.3	30.6

Clarke County.—Analysis of lignite from Choctaw Corner, Clarke County:

	<i>Moisture as Received</i>	<i>Calculated to Dry Basis</i>
Moisture	26.3%	
Volatile matter	33.8	45.9%
Fixed carbon	28.5	38.7
Ash	11.4	15.4

Analysis of lignite from Bashi Creek, Sec. 8, T. 11 N., R. 1 E., Clarke County:

	<i>Moisture as Received</i>	<i>Calculated to Dry Basis</i>
Moisture	36.6%	
Volatile matter	27.0	42.7%
Fixed carbon	21.5	33.8
Ash	14.9	23.5
Sulphur 3.11%		

Lamar County.—Analysis of lignite from Wheeler Place and practically on the State line, Sec. 36, T. 16 S., R. 17 W., Lamar County:

	<i>Moisture as Received</i>	<i>Calculated to Dry Basis</i>
Moisture	18.5%	
Volatile matter	30.9	37.9%
Fixed carbon	27.5	33.8
Ash	23.1	28.3

Marengo County.—Analysis of lignite from a water well near Magnolia Station, Sec. 4, T. 13 N., R. 4 E., Marengo County:

	<i>Moisture as Received</i>	<i>Calculated to Dry Basis</i>
Moisture	29.6%	
Volatile matter	29.1	41.3%
Fixed carbon	31.8	45.2
Ash	9.5	13.5
Sulphur 3.7%		

Analysis of lignite from Pickens Landing, Tombigbee River, Marengo County:

	<i>Moisture as Received</i>	<i>Calculated to Dry Basis</i>
Moisture	12.4%	
Volatile matter	42.2	48.1%
Fixed carbon	36.6	41.9
Ash	8.8	10.0

Analysis of lignite from Landrums Creek in Sec. 23, T. 14 N., R. 1 E., near Nanafalia, Marengo County:

	<i>Moisture as Received</i>	<i>Calculated to Dry Basis</i>
Moisture	13.0%	
Volatile matter	41.4	47.9%
Fixed carbon	35.9	41.6
Ash	9.1	10.5
Sulphur 3.43%		

Monroe County.—Analysis of lignite from Sec. 31, T. 10 N., R. 7 E., Monroe County:

	<i>Moisture as Received</i>	<i>Calculated to Dry Basis</i>
Moisture	34.5%	
Volatile matter	28.7	43.8%
Fixed carbon	17.1	26.1
Ash	19.7	30.1
Sulphur 2.86%		

Pike County.—Analysis of lignite from Deer Creek three miles southeast of Glenwood, Pike County:

	<i>Moisture as Received</i>	<i>Calculated to Dry Basis</i>
Moisture	24.1%	
Volatile matter	40.2	53.0%
Fixed carbon	24.3	32.0
Ash	11.4	15.0
Sulphur 3.11%		

Analysis of lignite from Deer Creek about three miles southeast of Glenwood, Pike County:

	<i>Moisture as Received</i>	<i>Calculated to Dry Basis</i>
Moisture	15.9%	
Volatile matter	34.7	41.3%
Fixed carbon	38.7	46.0
Ash	10.7	12.7

Sumter County.—Analysis of lignite from cut along the Alabama, Tennessee and Northern Railroad about five miles south of York, Sumter County:

	<i>Moisture as Received</i>	<i>Calculated to Dry Basis</i>
Moisture	35.7%	
Volatile matter	31.6	49.2%
Fixed carbon	29.4	45.7
Ash	3.3	5.1
Sulphur 1.95%		

Wilcox County.—Analysis of lignite from Coal Bluff on the Alabama River, Wilcox County:

	<i>Moisture as Received</i>	<i>Calculated to Dry Basis</i>
Moisture	26.0%	
Volatile matter	40.3	54.5%
Fixed carbon	20.7	28.0
Ash	13.0	17.5
Sulphur 3.10%		

Analysis of lignite from Coal Bluff on the Alabama River, Wilcox County:

	<i>Moisture as Received</i>	<i>Calculated to Dry Basis</i>
Moisture	11.2%	
Volatile matter	45.7	51.5%
Fixed carbon	32.0	36.0
Ash	11.1	12.5
Sulphur 3.74%		

Analysis of lignite from Yellow Bluff on the Alabama River, Wilcox County:

	<i>Moisture as Received</i>	<i>Calculated to Dry Basis</i>
Moisture	15.0%	
Volatile matter	39.4	46.4%
Fixed carbon	29.2	34.3
Ash	16.4	19.3

Analysis of lignite from Yellow Bluff on the Alabama River, Wilcox County:

	<i>Moisture as Received</i>	<i>Calculated to Dry Basis</i>
Moisture	11.1%	
Volatile matter	37.2	41.9%
Fixed carbon	19.3	21.7
Ash	32.4	36.4

The ash from a composite sample of lignite from Coal Bluff and from Yellow Bluff on the Alabama River, Wilcox County, gave 1.34 per cent potassium oxide on analysis.

METHODS OF MINING

No commercial production of lignite has been reported in Alabama, but there are many reports of this material having been dug from outcrops in small quantities, usually by local blacksmiths for use in forges. Thus no methods of mining have been tried in the State, but the one that appears most promising is the strip pit method, in which the overburden is removed usually by steam shovels, drag line excavators or hydraulic giants, and the underlying lignite is taken out from the open cut with steam shovels.

It is obvious that the overburden must be light for this method of mining to be profitably employed. The writer has not seen any large areas in which the overburden is light and naturally as the bed is following down the dip the thickness of the cover increases, but as a general rule, the overlying material is composed primarily of sand and clay, which can be removed rather cheaply. The proportion of overburden to lignite that can be profitably removed depends upon a number of conditions, the most important of which are the quality and extent of the beds and the nature of the overlying materials. Obviously, a much greater thickness of cover consisting of sand and clay than that consisting of hard rock can be removed, other conditions being equal. It cannot be said just what this ratio would be in the south Alabama area but perhaps not more than three feet of overburden could be removed for each foot of workable lignite.

The open pit mines do not require as large a percentage of skilled workmen as the underground mines and the expense of timbering, ventilating and lighting is eliminated. Accidents due to falls of roofs, explosions and poison gas, so common in the underground mines, are practically unknown. On the other hand, there is likely to be considerable loss of time in the open pit mines, due to weather conditions and the water, which collects in the pits, must be pumped out at additional expense. In some cases it may be difficult to dispose of the strippings.

Underground methods of mining, as well as the strip pit method, have been successfully employed for a number of years, in the western States, where extensive beds of lignite occur. The larger mines are usually operated by the underground method, but the strip pit method is fast gaining in favor. The underground mines are opened either by a shaft, slope, drift or tunnel.

A shaft is a vertical opening driven from the surface to the lignite beds, which serves as an entrance to the mine and as a passageway for

ventilation. The lignite is hoisted to the surface in skip cars by means of engines. Usually the shafts are timbered, but in some cases it may be desirable to install a more permanent lining, such as concrete or bricks, and as would be expected, the timbered shafts are as a rule square or rectangular, while those lined with concrete or bricks are generally round or elliptical.

A slope is an inclined opening driven from the surface and may or may not follow the bed to be mined. If the slope is steep, the materials are hoisted out as in the shaft mines, otherwise, mules or electrical locomotives are used to pull the material to the surface in cars.

A drift is an opening driven from the outcrop along the bed and is almost horizontal in most cases.

A tunnel is an opening driven practically horizontal from the side of a hill. In both the drift and tunnel mines, the lignite is pulled out in cars by mules or electrical locomotives.

The rectangular room and pillar method as used in the bituminous coal mines is followed. Since the materials immediately overlying the beds are not satisfactory for a mine roof, from one to four feet of lignite is left for this purpose, and as a result, very little timbering is necessary, except along the openings. Both the roof and pillars are robbed as soon as the rooms have been worked out, and the mining has advanced, with the result that caving invariably follows, due to the failure of the overlying strata of sand and clay.

The lignite is either undercut and shot down, or shot directly from the solid face. Shooting does not seem to have the injurious effect that it has upon the bituminous mines, due to the fact that the associated materials are only slightly consolidated, if at all. The loosened material may be loaded in cars, either by hand or machinery.

Ordinarily, very little water is encountered in the lignite mines, since the seams are usually overlain and underlain by beds of impervious clays, but the mines should be located above the level of the flood plains of the adjacent streams in order to prevent the accumulation of water and to eliminate the extra expense of pumping.

The faults and folds which are so frequently encountered in the bituminous districts, do not seem to occur in the lignite areas of the State. Both water and rail transportation are available.

PRODUCTION

Due to the relative thinness of the lignite beds in Alabama and economic conditions in general, these deposits have not been developed to any extent, but this does not necessarily mean that they cannot be economically worked, for in North Dakota and Texas in the United States, in the Dominion of Canada and in several European countries, the most important of which are Germany, France, Italy and Czecho-Slovakia, lignite has been profitably mined for many years. The most extensive deposits in the United States, as has been indicated above, are found in North Dakota and Texas, but deposits of lesser extent occur in South Dakota, Louisiana, Arkansas, Montana, Nevada, Wyoming, Mississippi, Tennessee and Kentucky.

The production of lignite in the United States in 1926 was about 2,859,000 tons, of which 1,370,000 tons were mined in North Dakota, 921,000 tons in Texas, 54,000 tons in Eastern Montana and 14,000 tons in South Dakota.

The North Dakota deposits¹ occur in both the Cretaceous and Tertiary systems, but by far the greater number of beds are found in the Tertiary. The beds vary in thickness from a few inches to thirty-five feet and more, and it has been estimated that they extend over an area of 32,000 square miles, of which 28,000 square miles contain at least one workable seam. In certain areas there are as many as fifteen to twenty seams in the vertical section, but not all of these are of workable thickness. In North Dakota a bed of lignite four feet or more thick is considered workable. Many of the beds have been traced as far as fifty miles and have an estimated areal extent of 1,000 to 2,000 square miles. The available reserve has been estimated at 516,000,000,000 tons, which it would seem is almost inexhaustible. In 1923 the state mine inspector reported 259 producing mines, with a total output of 1,435,605 tons, valued at \$3,743,413, which amounts to approximately \$2.59 a ton. This list includes both underground and strip pit mines, but does not include a number of small country mines, which were operated only part of the year to supply local consumption and thus were not reported.

The Texas lignites are found in the Gulf Coastal plain and are very similar in occurrence to the Alabama deposits. The most important beds occur in the Wilcox group of formations, which belongs to the Eocene

¹ Lignite Deposits of North Dakota, Bulletin No. 4, *North Dakota Geological Survey*, 1925.

period of the Tertiary era. However, other somewhat less important deposits appear in the Yegua and Jackson strata of the same period. These beds vary in thickness from a few inches to fifteen feet and more, the greater number being from two to four feet, although seams from five to ten feet are frequently encountered, and most of the mines work beds of this size. Both the strip pit and underground methods of mining are employed. According to Phillips,¹ the lignite fields of Texas extend over an area of 50,000 square miles, with an estimated available reserve of 30,000,000,000 tons. Although these beds have been worked for a number of years, a very slight impression has been made upon the total quantity available. The Bureau of Economic Geology of the University of Texas reported twenty-three producers of lignite in Texas during 1927, with a total output of 1,206,235 tons valued at \$1,534,798. This represents an average price of \$1.27 per ton.

USES

The primary use of lignite is for fuel purposes. The raw or run of mine material may be used for direct firing, as it comes from the mine, or it may be desirable in some cases to convert it into a treated or artificial form such as briquets, powdered lignite or gas.

It has been shown that if proper precautions are taken lignite in the raw state can be adapted to most domestic and industrial purposes. The principal changes must be made in the grate and draft arrangement of the furnace and the method of firing. Since the fuel crumbles even more readily upon quick drying in the furnace than it does upon slow drying at normal temperatures, the grate bars must be spaced close together to prevent loss from the fine unburned material being wasted with the ashes. The stoves and furnaces should have ample draft with a close adjustment. Lignite contains a high percentage of volatile combustible matter and is quick-burning, but its fuel value is much lower than that of bituminous coal, and naturally more of it must be burned to produce the same heat. The large amount of water which it contains, even after air drying, must be evaporated by the heat liberated upon combustion of the fuel, and thus reduces the available heating value to that extent. The ash usually contains pyrite and oxides of sodium and potassium, which tend to form clinkers on the grate bars of the furnace.

¹Phillips, William Battle; "The Fuels Used in Texas," *University of Texas Bulletin* No. 307, 1913.

The use of powdered fuel has gained favor in recent years, and it seems that lignite, due to its high content of volatile combustile matter and its quick-burning property, is well suited to this form of utilization. Powdered fuel is not satisfactory for domestic uses, but is especially well suited for the production of steam and for other industrial purposes, such as cement burning where a long flame is desirable. This form of utilization of lignite would overcome the undesirable property of crumbling upon drying, but there would remain the disadvantages of its low heating value and its tendency to form clinkers on the grate bars of the furnace.

An interesting new method of utilizing lignite is as a colloidal fuel, which is prepared by suspending the finely powdered material in fuel oil.

Most of the objections to lignite as a fuel may be overcome by pressing it into briquets, which may be accomplished in two general ways; by pressing alone and by pressure together with a suitable bonding or cementing material. In either case heat must be applied, but the temperature should not reach such a point as to oxidize the combustible materials.

The following method of briquetting worked out by the North Dakota School of Mines, and its sub-station appears to be successful and sufficiently inexpensive for commercial application, at least in that state. The run of mine lignite is first dried to eliminate all water and is then heated in a closed retort at a comparatively low temperature so as to drive off the volatile gases and tar, a treatment which is very similar to that employed in the low temperature carbonization of bituminous coal. The concentrated residue, or char, is then bound together with coal tar pitch as the cementing material into very satisfactory briquets of convenient size, depending upon the purpose for which they are to be used. The gaseous by-products from the carbonization process are recovered and utilized, thus helping to defray the expense of briquetting. These gases are used primarily for heating purposes and would serve as a cheap fuel for the production of power in steam plants and for other industrial purposes. The relatively small amount of ammonia produced by the carbonization process is recovered from the gases and finds a ready market for the manufacture of fertilizer.

It is evident that lignite used for this purpose must have a low ash content, for upon the elimination of the volatile matter the increase in the percentage of ash in the concentrated residue is in the same ratio as the resulting increase in fixed carbon. It would not be economical to trans-

port and handle briquets containing a high percentage of ash, and in addition such briquets would have an unduly low heating value.

Both organic and inorganic bonds have been suggested and tried, but the inorganic ones have been practically abandoned, due to the fact that the addition of any inorganic material increases the ash content of the final product and may encourage the formation of clinkers in the furnace. The most common organic bonds are coal tar, starch paste, molasses, asphalt, sulphite mill liquor, and coal tar pitch. Coal tar was the first bonding material used in the manufacture of briquets, but the product formed was not strong enough to withstand long transportation and softened when stored in hot climates, and upon exposure to the sun. The coal tar present gives off a dense black smoke and a disagreeable odor on burning.

Starch paste and dextrin has been successfully employed as a bonding material, however, it is too expensive to be used on a commercial scale.

Molasses has been used as a bonding material in the manufacture of briquets, and the product is very satisfactory, except that it takes up water from the air. It has been claimed that the addition of a small amount of linseed oil will render the briquets impervious to moisture and overcome this difficulty.

Some of the natural asphalts have been found to have excellent bonding qualities, and to have the right consistency for easy working. The briquets formed are tough and elastic, but somewhat porous and softer than those formed from coal tar pitch.

The cheaper grades of resin can be used as a bonding material to good advantage, and the briquets produced are hard and compact, but brittle. Due to their brittleness, the briquets cannot withstand transportation or rough handling.

Sulphite mill liquor, a waste product in the manufacture of paper, has been used to some extent in the manufacture of briquets. This material may be had very cheaply, since it is ordinarily a waste product, and it has proven very satisfactory as a bonding material.

Pitch, a by-product in the manufacture of coke, has been found the most satisfactory bonding material for the manufacture of briquets. The amount of pitch required varies from 4 to 10 per cent of the lignite used. The product is very hard and compact; it may be transported for great distances without damage; it will not crumble or break up upon handling and may be stored successfully.

Briquets give a more concentrated heat than the untreated lignite and in addition are clean, strong, of a convenient size and easily handled. In fact, lignite treated in this way approaches bituminous coal as a fuel for practically all domestic as well as industrial purposes.

It has been shown that lignite can be successfully utilized for the manufacture of producer gas, water gas and coal gas, each of which is well suited as a fuel for a number of industrial purposes, such as lime, cement and pottery burning, the manufacture of glass and bricks and the production of steam for power. The gasified lignite has also been successfully employed as a fuel for internal combustion engines. However, this practice has lost ground in recent years. The gases have a low illuminating power, and must be enriched when used for lighting purposes. The results of the producer gas tests made at the St. Louis exposition in 1904 are given below:

"It has been shown that a gas of higher quality can be obtained from lignite than from high grade bituminous coal, and that one ton of lignite used in a gas producer plant will yield as much power as the best Pennsylvania or West Virginia bituminous coals used under boilers. It appears, in fact, that as coals decline in value when measured by their steam-raising powers, they increase in value comparatively as a fuel for the gas producers.

"The brown lignites on which tests were made at the coal testing plant were from North Dakota and Texas, and the unexpectedly high power producing qualities developed by them in the gas producer and gas engine give promise of large future developments in these and other states in the far West, where extensive but almost untouched beds of lignite are known to exist."¹

¹ U. S. Geological Survey—Professional Paper No. 48, page 30.

COMMON MISCONCEPTIONS

The most common misconceptions in connection with the occurrence of lignite is that the beds get better and thicker farther from the outcrop and that the lignite improves with depth. If we disregard a few feet of weathered material near the outcrop, there is no evidence to support either of these statements. It is true that pressure is one of the factors in the conversion of lignite into hard coal, but the additional pressure due to the weight of a hill would not have any appreciable effect. The seams as a general rule are extremely variable, both in thickness and quality, and there are as good reasons to believe they will become poorer away from the outcrop as to believe they will improve. In many cases the beds are lens shaped and obviously whether they thin or thicken, farther in the hill, depends upon the place at which the outcrop occurs on the lens.

It does not seem probable that bituminous coal occurs below the lignite beds in South Alabama, but if it occurs at all it would be in the Carboniferous system, and there is no proof that these strata extend so far south. Deep wells in the southeastern part of the state have shown that the Carboniferous does not exist there, and that the Cretaceous and Tertiary strata rest directly upon the crystalline rocks. Assuming that the bituminous coal does exist below the lignite, it is certainly at such a depth as to prevent mining it economically, if at all.

It has been shown that lignite belongs to a much later geological age than stone coal, and naturally its presence is evidence that stone coal does not exist in the area.

It seems appropriate at this place to answer a question often put to the field man, "How long will it take the lignite to change to stone coal?" This question may be of scientific interest, but it certainly has no practical value to the present land owner or miner, since it has been shown that vast periods of time are necessary for this change. In fact, the rate of transformation is so slow that the change occurring in a lifetime would not be noticed. Thus it is evident that this change will be completed in the very remote future, but from a practical standpoint does not concern anyone now living. At the present time, therefore, lignite must be treated as such and not as potential bituminous coal.

CONCLUSION

From the foregoing it would seem that the future of the Alabama lignite depends upon its utilization for fuel purposes near the occurrence, and at the present time there are no industries in this area requiring large amounts of fuel. Lignite is well suited for burning cement, lime, pottery, pipes, tile, bricks and glass, and suitable raw materials for the manufacture of these products may be had comparatively close to the occurrences. The Selma chalk and the Ocala and Marianna limestones have been successfully utilized for the manufacture of cement for a number of years, while certain beds of limestone belonging to the Vicksburg and Jackson groups are very pure and would be satisfactory for the manufacture of lime. Many excellent beds of clay occur in this area which are well suited for the manufacture of bricks, tile, pipes, pottery and possibly chinaware. As has been stated before, there is usually a bed of clay immediately underlying the lignite which could, in many cases, be mined along with this material at small additional expense.

A probable use of lignite on a large scale would be as a fuel for steam plants generating electrical power. It is necessary that companies supplying hydroelectric power have reserve steam plants to furnish power during low water and other abnormal times, and it is desirable to locate the reserve plants comparatively close to the district in which the power is to be supplied. Since bituminous coal must be shipped into South Alabama from a considerable distance, lignite, if produced locally at a reasonable cost, would mean a decided saving of money in freight charges alone.

This method of utilization has been realized in a steam plant at Trinidad, Texas, and since the lignites in that state are similar to those occurring in Alabama, it seems advisable to give a short account of the process. This power plant, operated by the Texas Power and Light Company, uses powdered lignite for fuel and has a capacity of 40,000 kilowatts. The fuel has an approximate average composition of 33.33 per cent moisture, 35.93 per cent fixed carbon, 21.10 per cent volatile matter, 9.16 per cent ash and 0.48 per cent sulphur, with a heating value of 7,096 British thermal units per pound.

Although the boiler room efficiency is only moderate, approximately 75 per cent, and slightly more than two and one-half pounds of fuel are consumed to produce one kilowatt hour, the low cost of the lignite delivered at the plant reduces the fuel cost for each unit of power produced lower

than in many efficient modern steam plants burning bituminous coal. One of the main losses is due to the large proportion of moisture in the fuel, but contrary to the general opinion the ash is a very small source of loss, since it contains less than one per cent of combustible material. The plant requires one thousand tons of fuel daily, which is mined by both the strip pit and underground methods and hauled to the power plant, eight miles away, in railway dump cars. By very efficient methods, the fuel is unloaded and crushed between steel rolls so that 95 per cent of it passes a 0.75-inch mess screen, after which it is passed over steam pipes, which remove a small proportion of the moisture, to large Raymond pulverizers, where it is converted into powdered form for consumption. The powdered fuel is then blown into the furnace together with the amount of air required for its most efficient combustion. The drying and crushing process was expected to reduce the moisture content to approximately 18 per cent, but in actual practice only about 5 per cent of the total moisture is expelled.

From the very beginning no difficulty has been encountered with the actual burning of the powdered lignite, and the plant has proven very successful.

Another possible use of lignite would be as a fuel for drying and grinding ochers for use as pigments and fillers. Several important beds of this mineral occur in or near the lignite area of South Alabama, and are being worked to some extent at the present time.

It is interesting to note that lignite is used as the raw material for the manufacture of synthetic gasoline in a plant at Merseburg, Germany. However, the process could hardly be considered practical in the United States at the present time.

The gases produced from lignite may possibly serve as a cheap source of hydrogen, nitrogen, carbon monoxide, and the lighter hydrocarbons which have a number of commercial uses in addition to serving as the original materials in a number of chemical industries.

It has been shown that lignite can be successfully briquetted and in this form shipped and stored the same as stone coal, and that it is especially well suited for domestic purposes. Fuel treated in this way is obviously more expensive than the raw material, and economic conditions in Alabama do not at present warrant such a treatment. However, the practice may be considered a remote future possibility.

It must be remembered that Alabama is abundantly endowed with wood, bituminous coal and water power, with which it is hard for lignite to compete, and except for this condition, no doubt these deposits would long since have been developed.

INDEX

- Acre foot, 16.
- Air drying, 10, 54.
- Alabama River, 18, 20, 23, 41, 45, 49, 50.
- Alabama, Tennessee and Northern R. R., 15, 42, 49.
- Aluminous sandstone, 18.
- Aluminum oxide, 11.
- Analyses of Alabama lignites, 46.
- Analyses of lignite and bituminous coal, 12.
- Anthracite, 12, 13, 14.
- Areal extent of beds, 15.
- Arkansas, 53.
- Ash, 10, 11, 25, 54, 55, 56, 60.
- Asphalt, 56.
- Augurs, 16.
- Available tonnage, 15, 16.
- Bakerhill, 30, 46, 47.
- Barbour County, 18, 30, 46, 47.
- Bashi Creek, 34, 47.
- Bashi formation, 18, 20, 24., section of, 23.
- Bells Landing, 23, 41.
- Bellview, 46.
- Big Sandy Creek, 45.
- Bituminous coal, 9, 12, 54, 58, 61.
- Bluff Springs Church, 34.
- Briquetting, method of, 55.
- Briquets, 9, 54, 55, 56, 57.
- British thermal unit, 10, 11.
- Brown coal, 10.
- Butler County, 18.
- By-products, 9, 55.
- Calcium, 11.
- Calcium carbonate, 14.
- Canada, 53.
- Carbon, 11.
- Carbonaceous sands, 15.
- Carboniferous, 11, 13, 58.
- Carbon monoxide, 60.
- Char, 56.
- Character of beds, 15.
- Chemical analysis, 11, 12, 16.
- Chemical industries, 9, 60.
- Chemical properties, 11.
- Choctaw Corner, 47.
- Choctaw County, 18, 30, 33.
- Clarke County, 16, 18, 34, 47.
- Claybank Creek, 37.
- Clinkers, 10, 11, 54, 56.
- Coal Bluff, 18, 45, 49, 50.
- Coal Bluff seam, 18, 37, 38, 42, 46.
- Coal gas, 57.
- Coal tar, 56.
- Coastal plain, 26.
- Coffee County, 18, 34.
- Coke, 10.
- Colloidal fuel, 55.
- Color, 10.
- Conclusion, 59.
- Conecuh County, 18.
- Conecuh River, 18, 42.
- Consolidated marl, 18.
- Cooke, C. W., 20.
- Core drills, 16.
- Corrosive action, 10.
- Covington County, 18.
- Cracks, 14.
- Crenshaw County, 18.
- Cretaceous, 13, 18, 25, 26, 53, 58.
- Crumbling, see slacking.
- Crystalline rocks, 58.
- Cullom Springs well, 33.
- Cuttings, 16.
- Czecho-Slovakia, 53.
- Deer Creek, 42, 49.
- Description of lignite outcrops, 30.
- Development, 16.
- Dip, 18.
- Domestic fuel, 9, 54, 60.
- Draft, 11, 54.
- Drift, 51, 52.
- Drying, 9, 10, 60.
- Earthy impurities, 11, 25.
- Electric power, 9, 59.
- Eocene, 18, 25, 53.
- Erosion, 18, 20.
- Escarpment, 18.
- Eutaw formation, 25.
- Exposures, 14, 15.
- Ferric oxide, 14, 25.
- Ferruginous sandstone, 14.
- Fertilizers, 55.
- Fixed carbon, 11, 12, 55.
- Formation of lignite, 12.
- Fracture, 10.
- Fragments of lignite, 14, 25.
- France, 53.
- Fuel, value, see heating value.
- Fusibility of ash, 11.
- Gas, 11.
- Gasified lignite, 54.
- Gasoline from lignite, 60.
- Geology, 9, 18.
- Germany, 53, 60.
- Glaucinite, see greensand.
- Glaucinitic marl, 20.
- Glenwood, 42, 49.

- Grate bars, 54.
Great Dismal Swamp, 13.
Greensand, 18, 20, 25.
Ground waters, 14.
Hardness, 10.
Hatchetigbee Bluff, 24.
Hatchetigbee formation, 18, 20, 24, 26.
 section of, 24.
Heating value, 9, 11, 54, 56.
Henry County, 18.
Hydrocarbons, 60.
Hydrogen, 11, 60.
Igneous activity, 13.
Immature coal, 10.
Impervious strata, 14.
Impressions of plants, 25.
Indurated marl, see consolidated marl.
Inorganic bonding materials, 56.
Inorganic impurities, 11, 37.
Internal combustion engine, 57.
Introduction, 9.
Iron, 11.
Italy, 53.
Jackson formation, 54, 59.
Jackson, J. W., 42.
Kentucky, 53.
Kimbrough, 46.
Lamar County, 25, 37, 47.
Land plants, 12.
Landrums Creek, 20, 37, 48.
Lenticular shape of beds, 15, 58.
Lignite-fired steam plant, 59.
Lignite in North Dakota, 53.
Lignite in Texas, 53.
Lignitic clay, 14, 15, 16.
Lignitic sand, 15.
Lignitized logs, 14, 25.
Linden, 34, 37.
Little Flat Creek, 38.
Louisiana, 53.
Luster, 10.
Magnolia, 34, 48.
Mantle, 14.
Marengo County, 15, 18, 20, 37, 38, 48.
Marianna limestone, 58.
Merseburg, Germany, 60.
Midway, 25.
Mineral matter, 11, 12.
Mining methods, 51.
Misconceptions concerning lignite, 58.
Mississippi, 53.
Mode of occurrence, 14.
Moisture, 10, 11, 60.
Molasses, 56.
Monroe County, 18, 38, 41, 48.
Montana, 53.
Naheola formation, 25, 37.
Nanafalia formation, 18, 20, 24, 25, 37,
 section of, 23.
Nevada, 53.
Nitrogen, 11, 60.
North Carolina, 13.
North Dakota, 53.
Oaktuppah Creek, 33.
Ocala limestone, 59.
Open pit mines, 51.
Organic bonding materials, 56.
Organic portion of lignite, 11.
Ostrea thirsae, 18, 20.
Outcrops, 30.
Overburden, 51.
Oxygen, 11.
Partings, 16.
Peat, 10, 12, 13.
Peat bogs, 12, 13.
Peebles Landing, 45.
Phillips, W. B., 54.
Physical properties, 10.
Pickens Landing, 37, 48.
Pike County, 18, 42, 49.
Pillars, 52.
Pitch, 56.
Plant remains, 12.
Potassium oxide, 11, 50, 54.
Powdered lignite, 54, 55, 59.
Power plant, 9, 60.
Producer gas, 57.
Production, 53.
Proximate analysis, 11.
"Pseudo-buhrstone," 18, 20.
Pursley Creek, 46.
Pyrite, 10, 11, 15, 37.
Quality of lignite beds, 15.
Resin, 56.
Riderwood, 33.
Roof, 14, 52.
Russia, 13.
Saunders Ferry, 45.
Sediments, 11, 13, 24, 25.
Selma chalk, 59.
Semi-bituminous coal, 12.
Shaft, 51, 52.
Shell beds, 18.
Shooting, 52.
Silicon dioxide, 11.
Slacking, 9, 54, 55.
Slope, 51, 52.
Sodium oxide, 11, 54.

- South Dakota, 53.
Specific gravity, 10, 16.
Starch paste, 56.
Steam plant, 59.
Springs, 14.
St. Louis exposition, 57.
Stratigraphic section of southwest Ala., 27.
Stratigraphy, 26.
Streak, 10.
Stripping, 9, 51.
Strip pit mines, 51, 60.
Stumps of trees, 13.
Sub-bituminous coal, 12.
Sucarnoochee formation, 25, 26.
Sulphite mill liquor, 56.
Sulphur, 10, 11.
Sulphur dioxide, 11.
Sumter County, 15, 18, 26, 42, 49.
Swamp, 13.
Sweetwater Creek, 34.
Tallahatta Creek, 34.
Tallahatta formation, 20.
Tennessee, 53.
Tertiary, 13, 18, 25, 26, 53, 54, 58.
Test holes, 16.
Test pits, 16.
Texas, 53, 54.
Texas Power and Light Co., 58.
Texture, 10, 12.
Thickness, character and quality of beds, 15.
Thomasville, 16, 34.
Thrust pressure, 13.
Timbering, 52.
Tombigbee River, 18, 20, 24, 37, 48.
Topography, 18, 25.
Trinidad, Texas, 59.
Tunnel, 51, 52.
Tuomey, Michael, 9.
Turkey Creek, 46.
Tusahoma formation, 18, 20, 25, section of, 23.
Tuscaloosa County, 45.
Tuscaloosa epoch, 24.
Tuscaloosa formation, 24, 25, 26.
Ultimate analysis, 11.
Underground mines, 51, 60.
Uses of lignite, 54.
Vegetable accumulations, 12, 13.
Virginia, 13.
Volatile matter, 11, 12, 54, 55.
Warrior River, 45.
Water, 11, 12, 52, 54.
Water gas, 57.
Water power, 61.
Wheeler place, 37, 47.
Wilcox County, 15, 18, 20, 23, 45, 46, 49, 50.
Wilcox epoch, 24.
Wilcox group, 18, 24, 25, 53.
Wood, 61.
Workable thickness, 9, 53.
Wyoming, 53.
Yellow Bluff, 23, 45, 50.
Yellow Creek, 37.
York, 15, 42, 49.

